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Central Intelligence Agency

Washington, D.C. 20505

DIRECTORATE OF INTELLIGENCE

12 March 1985

Chinese Progress in the Production of Integrated Circuits [redacted] 25X1

Summary

One of Beijing's primary technology tasks is to develop a modern microelectronics industry that will enable China to produce for export as well as to meet its domestic requirements for electronic devices. Because many Chinese integrated circuits are unreliable and inefficient, Beijing now imports most electronic devices needed for key computers and military projects. [redacted] 25X1

China's present ability to produce integrated circuits lags behind the West by about 10 years. Devices are larger than their Western counterparts, require more power, and operate more slowly. Production problems include inadequate coordination between research and production units, limited availability of key pieces of quality-control and test equipment, and shortages of qualified midlevel engineers and managers. [redacted] 25X1

To remedy these deficiencies, China has begun a comprehensive reform of its R&D sector and an ambitious import program involving both complete production lines and key pieces of equipment. We expect these efforts to yield some significant

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This memorandum was produced by [redacted] of the Office of East Asian Analysis in response to a request from the Deputy Assistant Secretary for Trade Development, Department of Commerce. Questions and comments are welcome and may be addressed to Chief, China Division, [redacted] 25X1 25X1

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results over the next few years. For Western firms attempting to sell to China's electronics sector, China's expansion plans have opened up significant sales opportunities.

Introduction

China's highest technological priority is to establish a modern semiconductor industry capable of supporting an expanded computer development and manufacturing program. By 1990 the Chinese hope to develop a capability in advanced microelectronics equal to the United States' capability in the early 1980s. China's objectives are twofold:

-- To increase the sophistication of the devices produced domestically for use in advanced computers and in military systems.

-- To boost the supply of medium-level electronic components available for use in dual-use computers and in consumer goods.

In the longer term, Beijing intends to become a major exporter of integrated circuits and a strong competitor in the international marketplace for sophisticated electronic components. To accomplish these objectives, China has shifted its electronics modernization strategy from one emphasizing self-reliance to one of importing advanced technology and equipment from the West and Japan to speed the pace of development and to cut R&D costs.

Growth of the Industry

China's integrated circuit industry had its beginning in early 1956, when the leadership formed a national committee to develop plans for the rapid development of semiconductor devices. During the late 1950s, China produced prototype semiconductor diodes and transistors. In the early 1960s, it began to develop a production capability for discrete semiconductor components, and by 1965 at least 34 factories and research institutes were making semiconductor materials and fabricating semiconductor devices.

Despite dislocations caused by the Cultural Revolution, the electronics sector continued to grow between 1966 and 1976, chiefly because of its importance to strategic weapons development. As part of a nationwide policy of dispersing defense-related production to shield industry from enemy attack, China during this period constructed additional semiconductor research and production facilities in remote areas of China. As a result of this effort, four major electronic research and production centers were established in China's interior (Gansu, Sichuan, Yunnan and Guizhou Provinces), in addition to the electronic production centers in Beijing, Tianjin, Shanghai, and

several coastal provinces. These interior production plants are relatively sophisticated and continue to produce primarily for military customers. By mid-1971, the number of Chinese plants known to be engaged in series, batch, or experimental production of semiconductor components had grown to 82--more than double the number identified in 1965.

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In the late 1970s, China began a new push to acquire Western technology for the production of semiconductors and other sophisticated electronic goods. One major new production line for integrated circuits was planned during this period, a facility at the Jiangnan Radio Equipment and Materials Plant in Wuxi, Jiangsu Province. Production at the new plant has been held up by difficulties in obtaining US export licenses for needed new equipment, the need to refurbish some of the used equipment, and legal problems involving the US trade agent. When completed the Wuxi plant will for a time be China's largest integrated circuit factory, with a capacity of over 26 million linear integrated circuits per year.

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With the backing of the Leading Group for the Invigoration of the Electronics Industry, formed in 1982 and renamed and reconstituted in 1984, other facilities of similar size are also planned for Tianjin, Shanghai, Beijing, Shaoxing, Changsha and several other cities. Combined output for these major projects could reach several hundred million integrated circuits per year.

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Current Capabilities...

China's semiconductor industry today reportedly consists of more than 500 facilities, 200 of which are involved in some aspect of integrated circuit development and manufacture. The Chinese claim that the Ministry of Electronics Industry alone controls at least 140 factories, which produce an estimated 40 million integrated circuits a year. In addition, there are electronics research and manufacturing enterprises operated by the Ministry of Astronautics Industry, the Ministry of Posts and Telecommunications, the Ministry of Machine Building Industry, the Ministry of Light Industry, the Ministry of Public Security, and the Chinese Academy of Sciences.

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At present, China manufactures nearly 1,000 types of integrated circuits. Most are small-scale-integration (SSI) or medium-scale-integration (MSI) devices. More sophisticated devices, such as 16K random-access-memory (RAM) units, and 16K eraseable-programmable-read-only-memory (EPROM) circuits, and 8- and 16-bit microprocessors are also being manufactured, but in limited quantities and with low production yields.

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China's ability to produce integrated circuits in commercial quantities continues to lag behind the US and Japan by five to 10 years.

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Table 1

Type of Memory IC	Year First Commercially Available		
	US	Japan	China
1K DRAM	1970	1972	1978
4K DRAM	1974	1975	1981
16K DRAM	1976	1977	1985 (est)
64K DRAM	1980	1980	1989 (est)
256K DRAM	1984	1983	1992 (est)

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China's domestic requirements for microprocessors and advanced logic and memory devices are still being met primarily by imports from Japan and the US. 25X1

China's production capabilities in seven major categories of integrated circuits are described below:

TTL Circuits. Transistor-transistor-logic circuits constitute about 50 percent of China's total integrated circuit production. China produces five series of TTL circuits, all based on the Texas Instruments SN74/54 series. Some are produced to military specifications, able to function in temperatures ranging from -55 to +125° C. The Chinese claim that all TTL logic circuits being produced are directly interchangeable with their US-produced counterparts. China is particularly proud of its low-power Schottky (LSTTL) devices, 100 varieties of which are produced--most to military standards--by an integrated circuit plant in China's interior. This plant, the Tianguang Electrical Industry Factory, reportedly supplied some of the circuitry used in China's Galaxy supercomputer. The Tianguang plant of Gansu Province is benefitting from the modernization of its sister plant, the Tianguang factory of Shaoxing, Zhejiang Province. 25X1

ECL Circuits. China's emitter-coupled-logic circuits are modeled on the Motorola MC10100 and MC10500 series. These ultra high speed circuits, again produced to military specifications, are also made by Tianguang. In addition, China claims to use these circuits in missile guidance systems, satellite communications equipment, and microwave measurement devices. 25X1

General Purpose MOS Logic Circuits. Because of the relatively slow speed and high power consumption of PMOS (positive-channel metal-oxide-semiconductor) devices, China is gradually replacing them with CMOS (complementary MOS) technology. NMOS (negative-channel MOS) technology continues to be used extensively in Chinese microprocessors and memory devices. Mastering the complex CMOS manufacturing process has

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been more difficult, but China reportedly produces more than 70 varieties of CMOS circuits, including microprocessors, operational amplifiers, voltage comparators, and digital/analog converters. In 1982, China's domestic sales of CMOS circuits exceeded 3 million units.

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Dedicated Circuits. Chinese versions of these circuits--used in televisions, radios, watches, and other consumer goods--are mainly based on Japanese devices made by Sanyo, Toshiba, Hitachi, Matsushita, NEC, and others. In recent years, China has purchased equipment for a large number of production lines designed to produce devices for consumer electronics. Many contain refurbished equipment purchased from Japanese or US IC producers, rather than state-of-the-art production technology. Some of the production lines, such as the one at the Jiangnan Radio Equipment and Materials Corporation, may be capable of producing more advanced general purpose integrated circuits than required for color televisions--such as 8-bit microprocessors and 16K memory devices.

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Microprocessors. China produces 1-bit CMOS and 4-, 8- and 16-bit NMOS microprocessors. China's 8-bit microprocessors are modeled on Intel's 8080 and Motorola's 6800 series. China claims to be producing single-chip 8-bit processors in at least four different factories, although the chip is most likely significantly larger than its Western counterpart.

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In early 1984, China claimed to have begun small-batch production of 16-bit microprocessors at an interior factory subordinate to the Ministry of Astronautics Industry, the Lishan Microelectronics Corporation of Shaanxi Province. The 16-bit processor can be used in real-time control systems in demanding environments; it is designed to operate for long hours in a wide range of temperatures and is resistant to moisture and vibration.

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Memory Devices. In 1982, China announced that the Semiconductor Research Institute of the Chinese Academy of Sciences in Beijing had developed a 16K DRAM (dynamic-random-access-memory) chip. At the same time, Beijing made public its ability to produce 4K SRAMs (static-random-access-memory devices) and 8K EPROMs. Since then, the Chinese have developed 16K EPROMs. At least a dozen factories plan to produce 16K DRAM

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devices and are currently negotiating for the transfer of foreign technology and equipment.

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China reportedly began research on 64K DRAM integrated circuits in 1981 and claims to have produced them in small quantities in the Shanghai area by 1984.

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A number of institutes are now working to develop very-large-scale-integrated circuit (VLSI) technology. In 1983 and 1984, several Chinese facilities attempted to obtain equipment and information suitable for the production of 256K DRAM circuits.

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Even if China gains access to Western 256K DRAM production technology, the Chinese will probably not produce a prototype 256K DRAM before the end of this decade. Production capability will require several additional years.

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...and Limitations

In laboratory settings, lack of equipment, rather than expertise, is largely responsible for China's delay in producing advanced prototypes. Even with imported high-purity chemicals and materials, the absence of computer-aided-design (CAD) systems and state-of-the-art processing equipment prevents the Chinese from producing VLSIs on the order of a 256K DRAM.

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China's development of prototype 64K and 256K DRAM devices almost certainly requires the acquisition of equipment that will enable the Chinese to pack circuits more densely by using narrower design rules. The equipment generally available in Chinese factories permits the Chinese to produce devices with line widths of 5 to 10 microns, and the Chinese claim to have achieved a 2-micron capability in one institute. In contrast, Western producers routinely use 2-micron geometries and have made substantial progress toward developing a sub-micron capability.

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Another limitation of China's semiconductor industry is the long lead-time required before a developed prototype device moves into factory production. The gap between prototype and commercial production of memory devices, for example, ranges from two to four years and appears to have increased over the last decade, as the sophistication of the devices has risen. In the West, a one or two year gap between prototype development and commercial production--slightly longer for 256K DRAM devices--is the norm.

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Table 2

China's Development and Production of Memory Devices

Type of IC	Year Developed	Year Produced in Commercial Quantities
1K DRAM	1976	1978
4K DRAM	1979	1981
16K DRAM	1981	1985 (est)
64K DRAM	1984	1989 (est)

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Removing the Obstacles

China is taking steps to improve its ability to develop advanced devices on a laboratory scale as well as to improve production capabilities at its electronics factories. To remove the institutional barriers to advanced electronics production, Beijing is now embarked on a major reform of its entire scientific and technological system. Its aim is to bridge the gap between research findings and commercial production and to improve the flow of technology between factories. To foster the internal transfer of technology, the Chinese leadership is encouraging the mobility of technical personnel, creating financial incentives for institutes to work closely with factories on the development of new products and production techniques, placing a large number of institutes formerly controlled by the Chinese Academy of Sciences under the direct control of industrial ministries, and forming regional corporations, composed of factories and institutes engaged in semiconductor research and production, in major cities.

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To improve material conditions in laboratories and factories, Beijing has embarked on an ambitious program of equipment imports, factory renovation, and investment in key electronics production projects. Because China's goals involve both rapid expansion in the quantity of electronic devices produced for civilian applications and rapid advances in the sophistication of the circuitry produced for military uses, Beijing is using a variety of means to obtain foreign technology and equipment for this sector:

-- Cooperative production involving firms from the United States, Japan, and Western Europe. Although most of the emphasis on cooperative production in the

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electronics sector is centered on joint venture investment, the Chinese are also promoting compensation trade and kit assembly arrangements.

-- Purchases of turnkey plants and design technology for the production of advanced electronic devices. Although contracts for complete production lines have declined overall since 1978, the Chinese now appear more willing to purchase complete sets of equipment in the area of microelectronics.

-- Purchases of selected pieces of production and test equipment to modernize existing plants, improve production yields, and produce more sophisticated devices, such as large-scale and very-large-scale-integrated circuits.

-- Purchases of used pieces of equipment as well as refurbished complete production lines.

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Although it is difficult to generalize about the method Chinese factories most often select, key projects--frequently related to the production of components to be used in military systems--often involve new, rather than refurbished, equipment. Military-related projects are unlikely to involve any form of cooperative production that would require the presence of foreign managers or advisers. Joint venture projects, imports of used equipment, and purchases of complete production lines are the methods often chosen to boost the production of components to be used in consumer goods or general-purpose computers.

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Among the individual pieces of wafer fabrication equipment China most actively seeks to import are:

-- Microprocessor-controlled Czochralski furnaces for growing low-defect single-crystal silicon ingots.

-- Molecular-beam epitaxial reactors for growth of a layer of pure silicon (or gallium arsenide) on wafer surfaces.

-- Computer-aided design software, pattern generators and compilers, and graphics systems for developing mask designs.

-- Electron beam lithographic equipment for producing masks.

-- Projection mask alignment systems for use in photolithography.

-- X-ray lithographic equipment.

-- Ion implanters.

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-- Plasma etching reactors.

-- Magnetron sputtering equipment.

-- Wafer probers for circuit testing.

-- Automated gold wire bonding equipment.

-- Equipment for producing multilayer printed circuit boards.

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